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ABSTRACT

The state of the peripheral ending of the auditory analyzer of the internal ear was investigated during radiation sickness caused by a sublethal dose of X-ray radiation (350 R). Experiments were performed on guinea pigs. An objective method of recording the cochlear currents was used. It was established that when guinea pigs are irradiated with X-rays with a dose of 350 R an acute radiation sickness of the average degree is produced with a mortality of 50 percent. During the peak of the radiation sickness there is a decrease in the auricular reflex and a decrease in the bioelectric potentials of the cochlea at all frequencies by 3.9 to 9.1 decibels.

At the present time there is a large accumulation of literature pertaining to the action of penetrating radiation sources on the living organism. At the same time there are only a few observations and experimental investigations concerning the action of X-rays and γ -rays on the auditory apparatus. However, these works are based on a few facts which are frequently contradictory and which basically reflect the action of these rays during their local application.

Within the Soviet and foreign literature available to us the major work is that of I. L. Lopotko (ref. 4) which first illuminates the question concerning the state of the auditory organ during the general irradiation of the organism.

*Numbers given in margin indicate pagination in original foreign text.

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The investigation is of a purely morphological nature and gives no indication on the functional state of the auditory organ.

In 1952 two articles appeared by Novotny (refs. 14, 15), in which the author considered the question of X-ray action on the inner ear. Novotny investigated the region of the ear using doses from 1000 to 7200 R. The investigation of hearing was carried out six weeks after irradiation by taking the cochlear biocurrents. After this the animals (guinea pigs) were sacrificed in order to make a histological study of changes in the inner ear. As a result of the observations it was established that there is a decrease in cochlear potentials up to 8-15 decibels and corresponding morphological changes in the inner ear. However these articles consider the state of the auditory organ only during the local application of X-rays. /65

In 1954, I. A. Pigalev (ref. 7) showed that under conditions of general radiation a decrease in auditory perception is sometimes observed. Without presenting exact data and factual material, the author notes that by using the method of conditioned reflexes, an exact representation of the dynamics associated with the changes in the auditory function of dogs, during general irradiation of the organism, has been obtained.

During the meeting of the Leningrad oto-rhino-laryngological society in 1956, N. A. Pautov and N. I. Ivanov (ref. 6) reported on morphological changes in the inner ear under conditions of local and general irradiation. The results of the investigations point to substantial changes which occur in the inner ear during irradiation with X-rays. However, the work, which is based on a large amount of factual information, is of a morphological nature and does not throw light upon the functional state of the auditory organ.

From this short survey of the literature we can see that the question concerning the state of the auditory organ during the action of penetrating radiation on the organism has not been completely solved to date. Therefore, the Department of Medical Radiology, in collaboration with the Department of Ear, Throat and Nose Disease of the State Institute for the Advancement of Physicians, has carried out experimental work for the purpose of establishing the state of the auditory organ during general irradiation of the organism with X-rays, both from the morphological and functional point of view. The work was performed utilizing guinea pigs. The experimental work was carried out by the method of taking and recording the biocurrents of the inner ear (the microphonic effect of the cochlea). The measured biocurrents of the cochlea were photographed from the screen of the cathode ray oscilloscope and recorded on the loop oscillograph tape. In order to conduct the experiments with the irradiated animals an average hearing norm was established for intact guinea pigs and turned out to be close in its values to the average hearing norm for this type of animal (Table 1) obtained by other investigators (refs. 10, 11).

In order to compute the magnitude of hearing loss the following average values for the hearing norm were worked out (Table 2).

TABLE 1. THRESHOLD OF HEARING FOR GUINEA PIGS

Frequency, Hz (cps)	500	1000	2000	3000	4000	5000	6000	7000	8000
Value of hearing in decibels:									
According to Davis	90	110	100	80	60	55	55	50	50
According to Cowell	55	65	68	65	60	58	54	50	46
According to M. Ya. Kozlov	88	62	59	54	56	56	58	60	54

TABLE 2. HEARING NORM FOR GUINEA PIGS

Frequency, Hz	500	1000	2000	3000	4000	5000	6000	7000	8000
hearing, mu	9.47	17.5	15.75	15.75	13.3	10.5	8.3	5.25	3.08

A total of 120 guinea pigs were used in the experiments of which 13 perished when the method of narcosis was developed and when the biocurrents of the cochlea were taken; 10 were used to determine the hearing norm for this type of animal and 97 were subjected to general irradiation with an X-ray dose of 66 350 R. Of this number, 43 guinea pigs perished due to radiation sickness, 41 were tested for hearing during the peak of the radiation sickness and temporal bone was taken from 27 of these for histological investigation of changes in the inner ear.

Irradiation was carried out by means of RUM equipment under the following conditions: voltage 190 kV, current 20 mA, distance between skin and focus 60 cm, filter 0.5 mm Cu and 1 mm Al, dose power 20.6 R/min, irradiation time 17 min, total dose 350 R. The animals were irradiated in a special box 4-6 at a time.

As a result of observations made on the animals and data on pathological and anatomic investigations, it was established that animals subjected to a general X-ray radiation dose of 350 R developed acute radiation sickness of the average degree.

In our investigations it was possible to note three periods of radiation sickness development. The fourth period--the period of illness resolution--was not observed because the animals were sacrificed after experiment in the third period. The boundary lines between periods of illness were far from being clearly defined for all animals at all times. In the first period, which occurs immediately after irradiation, various disruptions in the functional state of the central nervous system were noted: most of the guinea pigs became passive and all their reflexes became retarded. The visible mucous membranes reacted to irradiation with hyperemia, the tympani were also hyperemic while the auricular reflex was sharply retarded. The animals refused water and food. After several hours, and in some animals after 2-3 days, all these symptoms disappeared and the guinea pigs had the appearance of healthy animals.

Then the second period of illness occurred--the period of apparent well-being. During this time only the count of leucocytes in the peripheral blood showed the insidious period of illness; the decrease in leucocyte content by the second day was already 55-60 percent. No other manifestations of the illness were noted. However, when the animals were observed towards the end of the week, the appearance of certain symptoms could again be noted; there was a gradual occurrence of sluggishness and the reflexes became less pronounced. The external appearance of guinea pigs also changed: they became less neat, their fur became tufty and lost its luster. Hyperemia of certain sections of the skin as well as of visible mucous membranes and tympani was observed. The auricular reflex gradually became more sluggish. In some animals, during this period (the period of pronounced clinical manifestations of the illness), there was a disruption of the gastroenteric tract, hoarseness in the lungs. The guinea pigs lost their weight progressively. Blood tests performed on the test animals every 3-4 days showed that by this time the number of leucocytes in the peripheral blood had decreased to 1500-1000. By the 9-14th day the illness reached its complete development and the animals perished with a sharply defined leukopenia and progressive weight loss. At the same time the following were observed: disruption of the gastroenteric track, adynamia and areflexia, extensive hemorrhages into the skin layer, mucosity of the mouth and nose, conjunctivas of the eyes and also refusal of water and food. It was at the peak of these manifestations of radiation illness that we carried out our experiments on the state of the auditory function of guinea pigs.

The function of the auditory organ was determined by the method of taking and recording the bioelectric potentials of the inner ear at the circular window of the cochlea. Surgery to approach the cochlea and the experiment for taking the biocurrents were carried out during urethan narcosis.

The auditory organ was excited by means of a dynamic speaker connected to an audio generator and to the operated ear by means of a thin rubber tube. /67 Four tones from 500 to 800 Hz inclusive were fed at a loudness of 120 db. The conditions of the experiment were always the same as confirmed by the constant background noise of the amplifier and of the oscillograph. The cochlea biocurrents after amplification were recorded on the MPO-2 loop oscillograph and also by photographing the curves from the screen of the EO-7 cathode ray oscilloscope using a camera with a special film holder and fluorographic film of high sensitivity. In addition to this, the deflection of the beam on the screen of the cathode ray was computed, the latter being graduated in millivolts. Later the data (in millivolts) obtained from the investigation of irradiated animals were compared with data obtained from intact animals and were converted to decibels by means of a special table.

While observing the progress of radiation sickness we were able to note the changes in the auricular reflex of guinea pigs which were irradiated. During the first period of radiation sickness the auricular reflex, as well as other reflexes, was depressed; however animals were encountered with insufficiently amplified reaction. During the second latent period of illness the reflex force became normal and the animals reacted well to acoustic stimulation.

Subsequently, with the development of radiation sickness, there was a gradual decrease in the auricular reflex, but in our experiments the reflex remained discernible during the entire third period. From these coarse observations we could judge that the acuity of hearing in animals gradually dropped as the sickness developed but hearing did not disappear completely.

In determining the cochlea bioelectric potential it turned out that there is a decrease in the electrical response of the cochlea at all test frequencies. Thus, by comparing auditory data obtained in the same manner for intact animals (Table 2) with data obtained for irradiated guinea pigs (Table 3), we can see that the magnitude of the bioelectric response of the cochlea of irradiated animals was always below the average normal values.

TABLE 3. THE VALUE OF BIOCURRENTS IN IRRADIATED ANIMALS

Frequency, Hz (cps)	500	1000	2000	3000	4000	5000	6000	7000	8000
Value of biocurrents, μ									
minimum	1.65	2.45	2.4	3.5	2.8	1.65	2.45	1.4	1.05
maximum	8.75	15.5	12.2	12.2	9.45	7.0	5.25	4.2	2.45

Using a special table to convert these data into decibels we obtain the values for the loss in hearing in decibels (Table 4).

TABLE 4. LOSS OF HEARING IN IRRADIATED GUINEA PIGS

Frequency, Hz (cps)	500	1000	2000	3000	4000	5000	6000	7000	8000
Loss of hearing, dB.									
minimum	5.0	2.0	3.0	2.0	3.0	3.5	3.5	2.0	2.5
maximum	25.0	24.0	19.5	19.5	22.0	20.0	18.0	12.5	9.2

From the above data we can determine the average hearing loss of guinea pigs during radiation sickness (Table 5). /68

TABLE 5. HEARING LOSS IN GUINEA PIGS DURING THE TIME OF RADIATION SICKNESS

Frequency, Hz (cps)	500	1000	2000	3000	4000	5000	6000	7000	8000
Hearing loss, dB.	9.0	9.1	8.8	7.9	8.7	7.2	8.0	4.2	3.9

One may think that this hearing loss is produced by the disruption of circulation during the peak of the radiation sickness, including the circulation of the inner ear, which produces certain disruptions in the physical, chemical and

electrobiological displacements. This in turn affects the functional state of the peripheral receptor of the auditory analyzer.

Conclusions

1. Data on the investigation of hearing obtained by the method of taking and recording cochlea biocurrents by various investigators are identical. Therefore, we can speak of the hearing norm for this type of animals.
2. A dose of 350 R during the general irradiation of guinea pigs produces acute radiation sickness of average degree and produces 50 percent mortality.
3. During the peak of radiation sickness in guinea pigs there is a decrease in hearing which is confirmed by the decrease in the auricular reflex and in the magnitude of the cochlea bioelectric response.
4. The decrease in hearing has been recorded at all frequencies from 500 to 8000 Hz in the range from 3.9 to 9.1 dB.

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